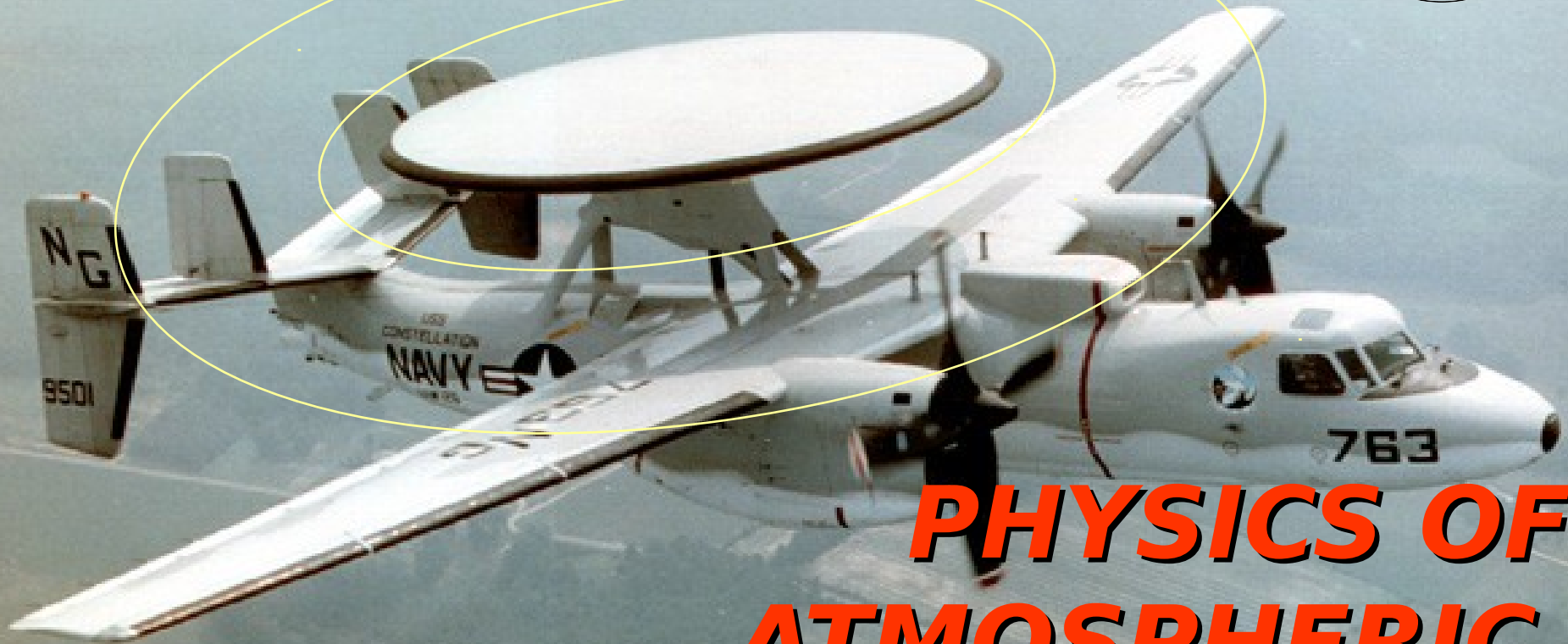


**Tactical**  
Modified for NPMOC Yokosuka and  
**Atmospherics**  
Detachments use.



***PHYSICS OF  
ATMOSPHERIC  
REFRACTION AND  
AREPS***

**Electromagnetic Energy or “EM” is all around us, all of the time. We need to know just what it is , and how it behaves in the atmosphere. When we are truly familiar with how atmospheric EM will affect Navy and Marine Corps weapons and sensor systems, we can truly say that we are providing the tactical decision maker with the best possible product. This lecture is designed to re-familiarize you with basic EM physical terms and definitions. So what is Refractivity?**

# **REFRACTIVITY (N)**

*The normal value of (n) near the earth's surface varies between 1.000250 and 1.000400.*

*Realistically, (n) is not a very convenient number, therefore, a scaled index of refraction known as **Refractivity (N)** has been defined.*

*It is apparent that (N) near the Earth's*

**The term refraction refers to the property of a medium to bend an EM wave as it passes through the medium. The degree of bending is determined by the index of refraction in the medium. Refractivity ( $n$ ) varies between 1.000250 and 1.000400, so we use a scaled index of refraction known as  $N$ . This  $N$  value varies between 250 and 400  $N$  units to give us a much easier number to use.**

# REFRACTIVITY (N)

**At microwave frequencies and below,  
the relationship between the Index  
of Refraction (n) and Refractivity (N)**

**for a**  
**be e**

$$N = (n-1) \times 10^6 = \frac{77.6p}{t} + \frac{e^2}{t^2} \times 10^5$$

**Where**

**p** = atmospheric pressure in millibars

**e** = partial pressure of water vapor in millibars

**t** = absolute temperature in degrees Kelvin

**Kelvin**

**QUESTION: Based on this equation what has the greatest influence on atmospheric refractivity?**

**ANSWER: Water Vapor.**

**QUESTION: Will EM refract towards or away from atmospheric layers containing a high water vapor content?**

**ANSWER: Towards the moist layer.**

**QUESTION: Where can we get all this information?**

**ANSWER: From a rawinsonde balloon.**

# **REFRACTIVITY (N)**

***Pressure and %RH rapidly  
with height, while the temp  
slowly, (n) and (N) both  
normally with increasing  
altitude.***

**In space EM waves travel in a straight line. On Earth the velocity of the wave is less than in space which makes the wave bend downwards.**

# MODIFIED REFRACTIVITY

- **(M) increases with height in a standard atmosphere.**
  - **Provides a convenient means for locating ducts.**
  - **When there is a decrease with height, this is a good indication of a trapping layer or duct.**
- $M = N + 0.048h$  for altitude in feet**

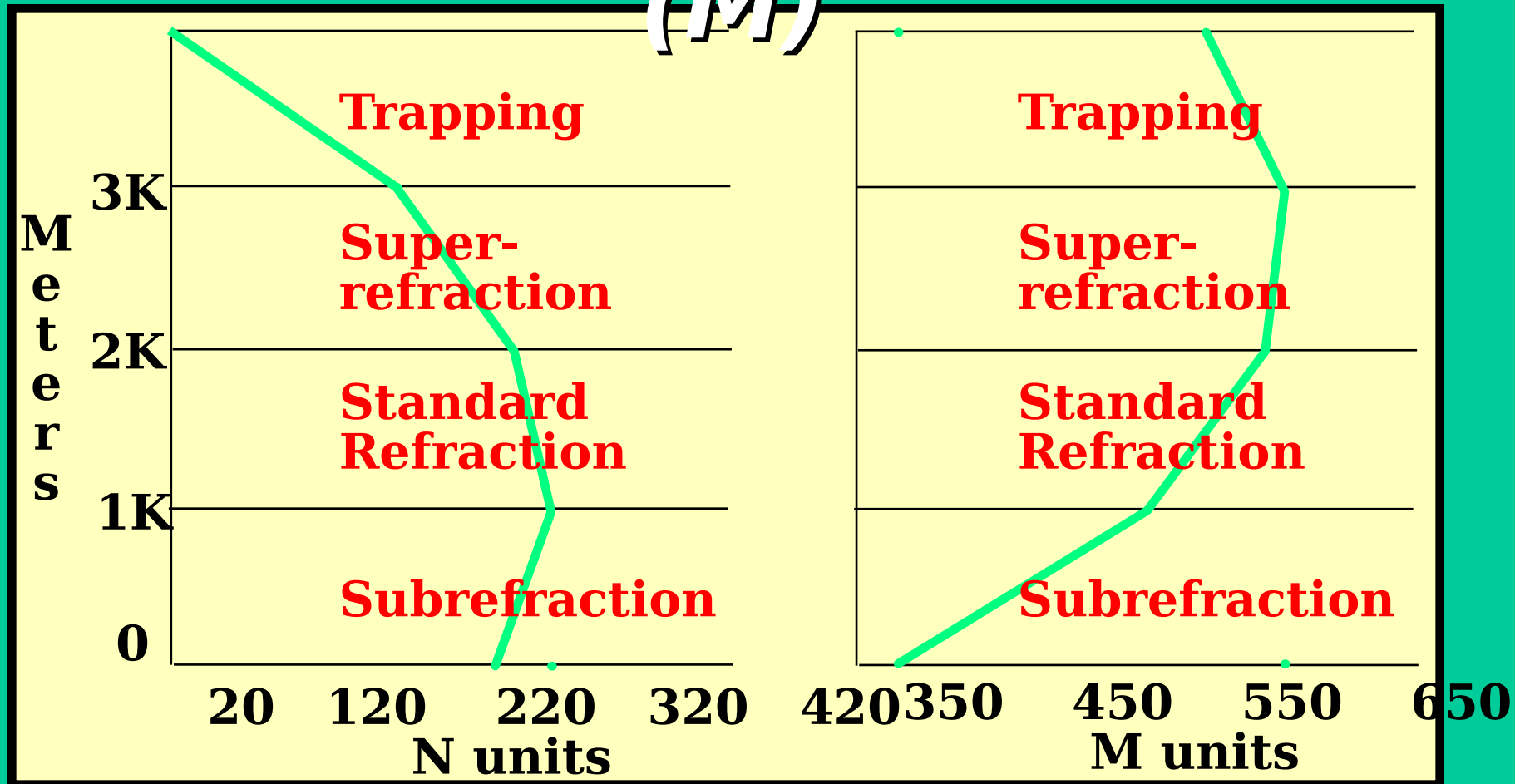
**The relationship between (M) and (N)**

# **REFRACTIVITY (N) and MODIFIED REFRACTIVITY**

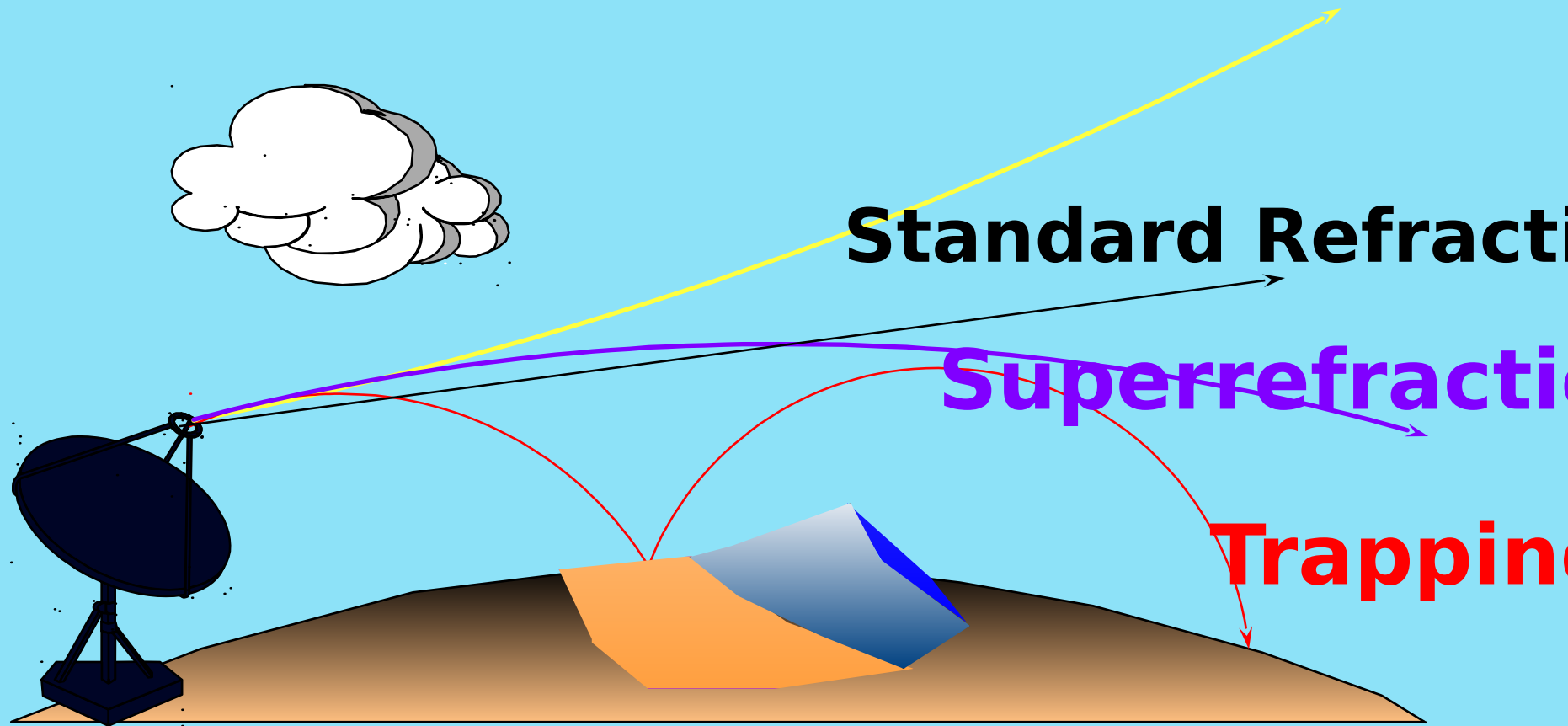
(M)

<b>Refractive Condition</b>	<b><math>\Delta N/Kft</math></b>	<b><math>\Delta M/Kft</math></b>
<b>Trapping</b>	<b><math>\leq -48</math></b>	<b><math>\leq 0</math></b>
<b>Superrefractive</b>	<b>-48 to -24</b>	<b>0 to 24</b>
<b>Standard Refraction</b>	<b>-24 to 0</b>	<b>24 to 48</b>
<b>Subrefractive</b>	<b><math>&gt; 0</math></b>	<b><math>&gt; 48</math></b>

# **REFRACTIVITY (N) and MODIFIED REFRACTIVITY (M)**



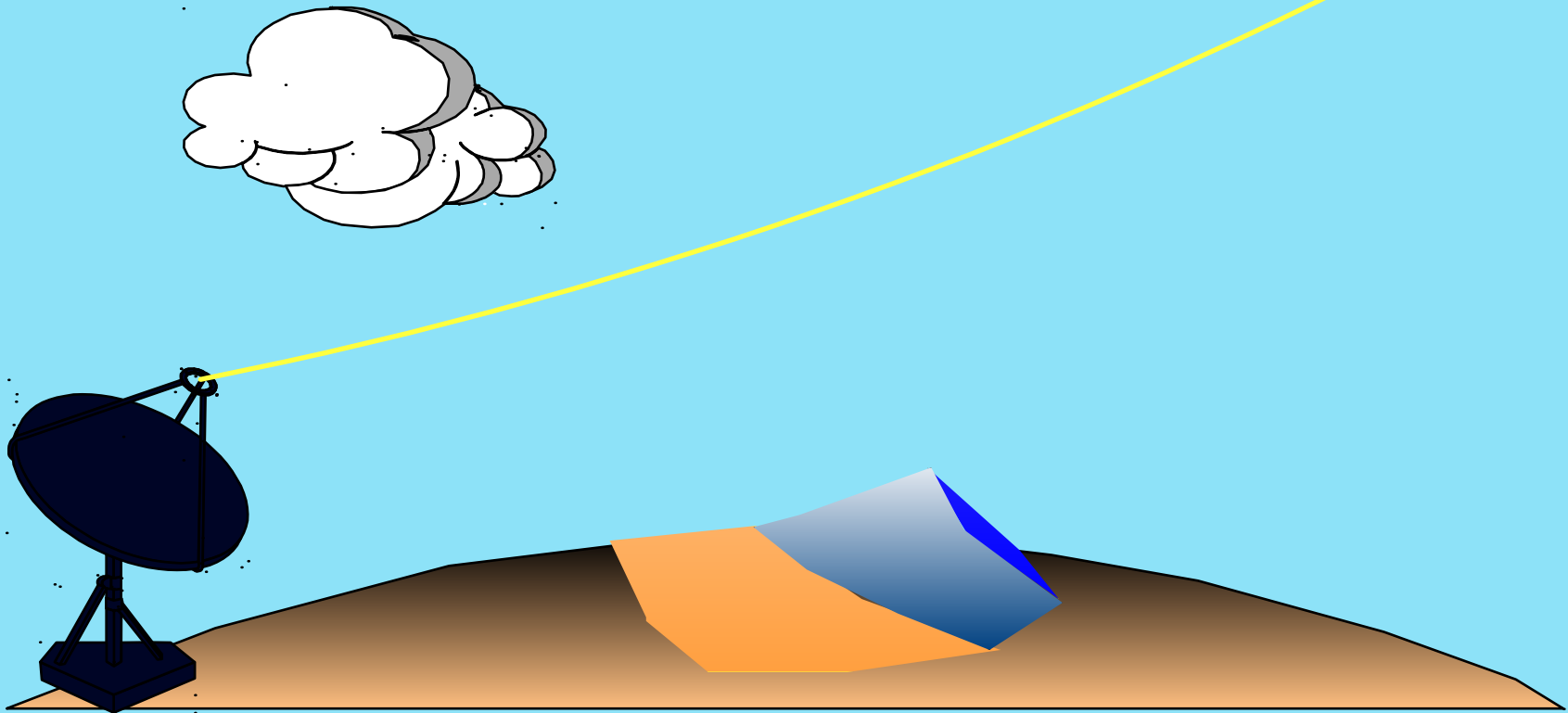
# What are the four types of Refractive Gradients?



# Refractive Gradients

A sub-refractive gradient can be described in which EM transmissions are refracted away from the earth's surface, or as an effective distance that is less than the visual horizon for Comms or radar.

## Subrefraction



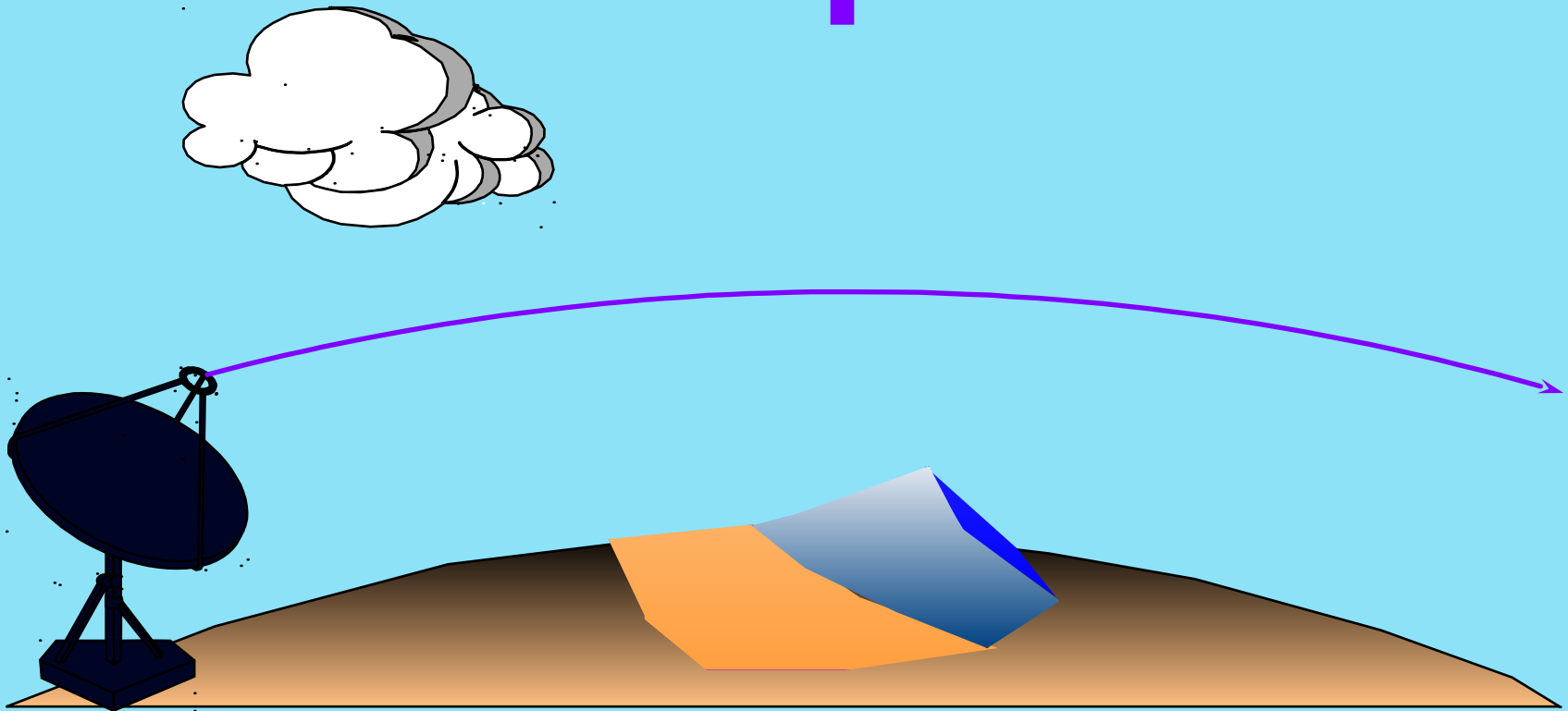
# **SUBREFRACTIVE**

- **DESERT OR ARID ENVIRONME**
- **SURFACE TEMP VERY HIGH**
- **VERY LOW WATER VAPOR CONTENT**
- **COOL, DRY AIR NEAR THE SURFACE WITH WARM, MOIST AIR ALOFT**
- **RARELY OCCURS IN NATURE**

# Refractive Gradients

A super-refractive gradient can be described as one in which EM transmissions are refracted downward towards the earth's surface and travel in a path that approaches, but does not quite reach the curvature of the earth's. Extended ranges can be expected from this type of propagation path.

## Superrefraction



# **SUPERREFRACTIVE**

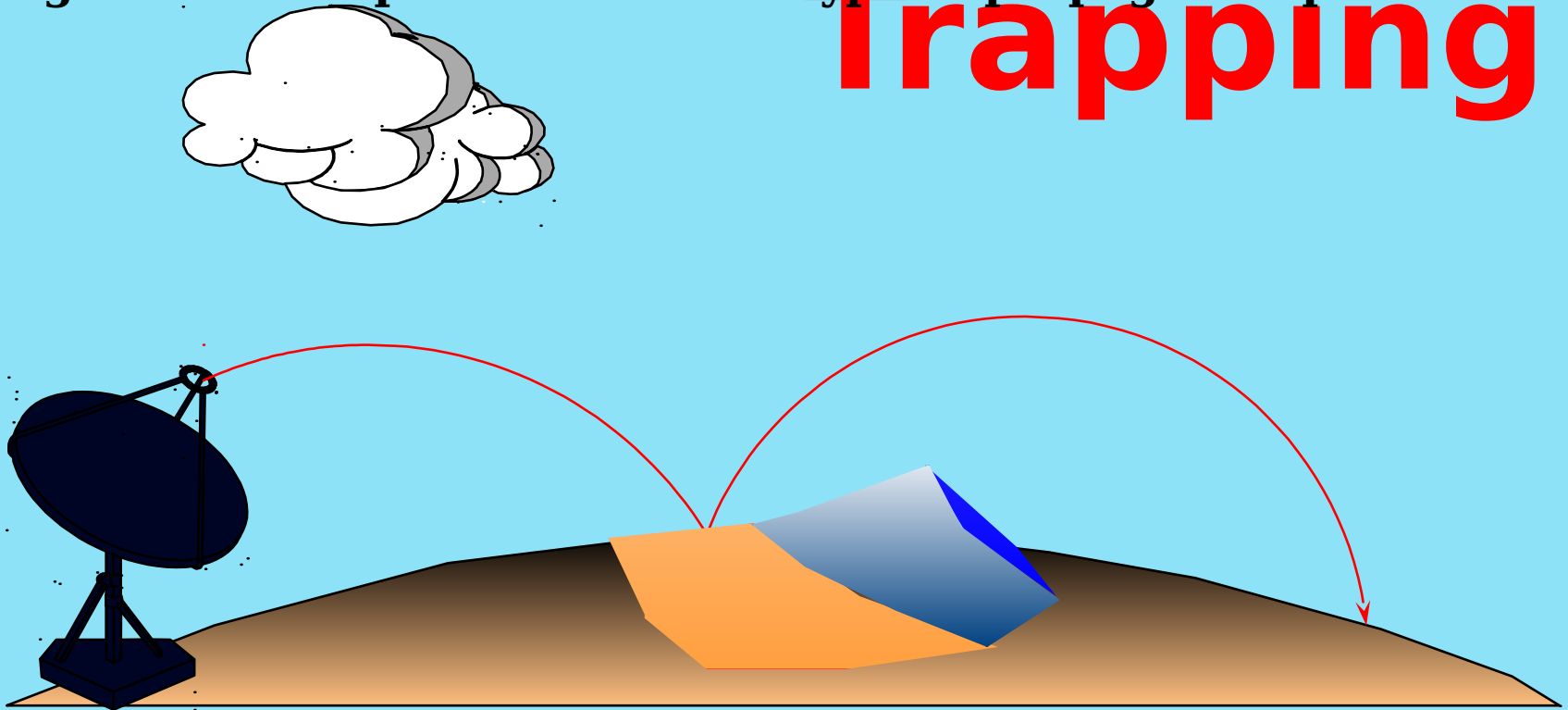
A sunset scene over a body of water. The sky is filled with large, dark clouds, and the sun is low on the horizon, creating a bright orange and yellow glow. A small boat is visible on the water in the distance.

- **INVERSIONS ALOFT, DUE TO LARGE SCALE SUBSIDENCE WILL LEAD TO SUPERREFRACTIVE LAYERS ALOFT**
- **EM TRANSMISSIONS FORCED TO REFRACT DOWNWARDS, BUT DO NOT QUITE REACH THE SURFACE**

# Refractive Gradients

A trapping gradient can be described as one in which EM transmissions are sharply refracted downwards to the earth's surface, strike the surface, are reflected upwards, and are henceforth again refracted sharply downwards to the surface, and so on, until the transmission is lost through interactions with the surface and atmosphere. Greatly extended UP TO FIVE TIMES THE NORMAL ranges can be expected from this type of propagation path.

## Trapping



# **TRAPPING**

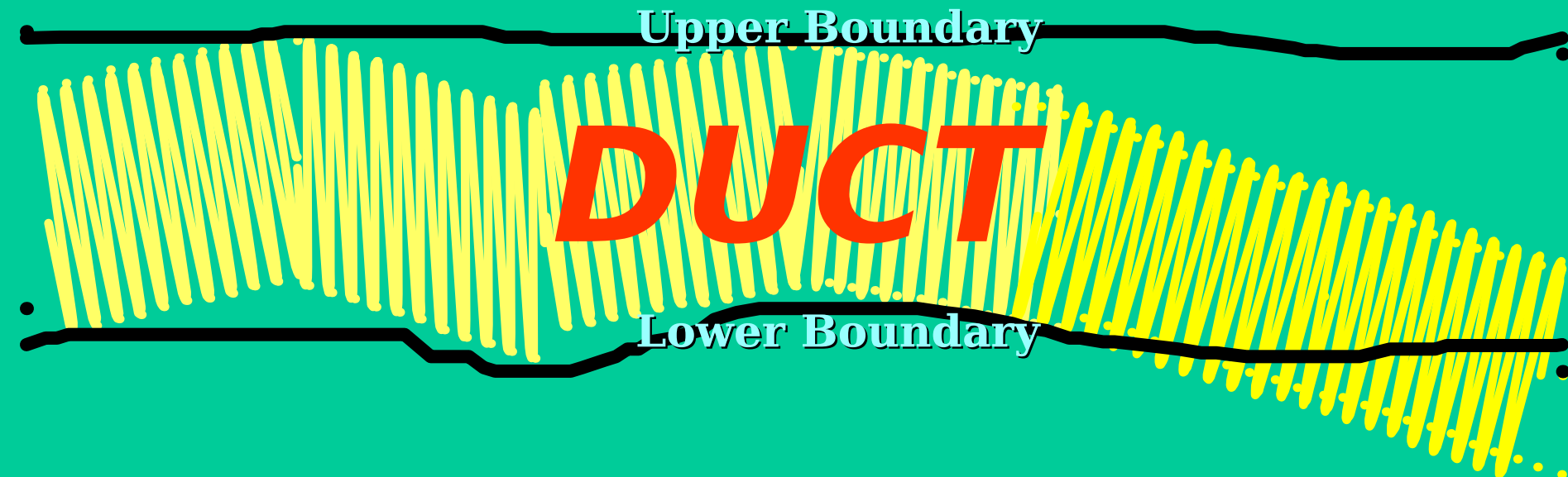
- ***WARM, DRY CONTINENTAL AIR ADVECTS OVER COOLER WATER (SANTA ANA, PERSIAN GULF)***
- ***CAUSED BY SUBSIDENCE AND FRICTIONAL HEATING ABOVE THE MOIST LAYER***

# ***DUCTING***



***A duct is a channel in which EM radiation can propagate far beyond it's***

*To propagate energy within a duct, the angle of incidence the EM energy makes with the duct must be small, usually less than 5 degrees. Thicker ducts can trap lower frequencies.*



# ***TYPES OF DUCTS***



# ***TYPES OF DUCTS***

*There are three types of Atmospheric ducts or channels to consider. They are:*

- ***SURFACE***

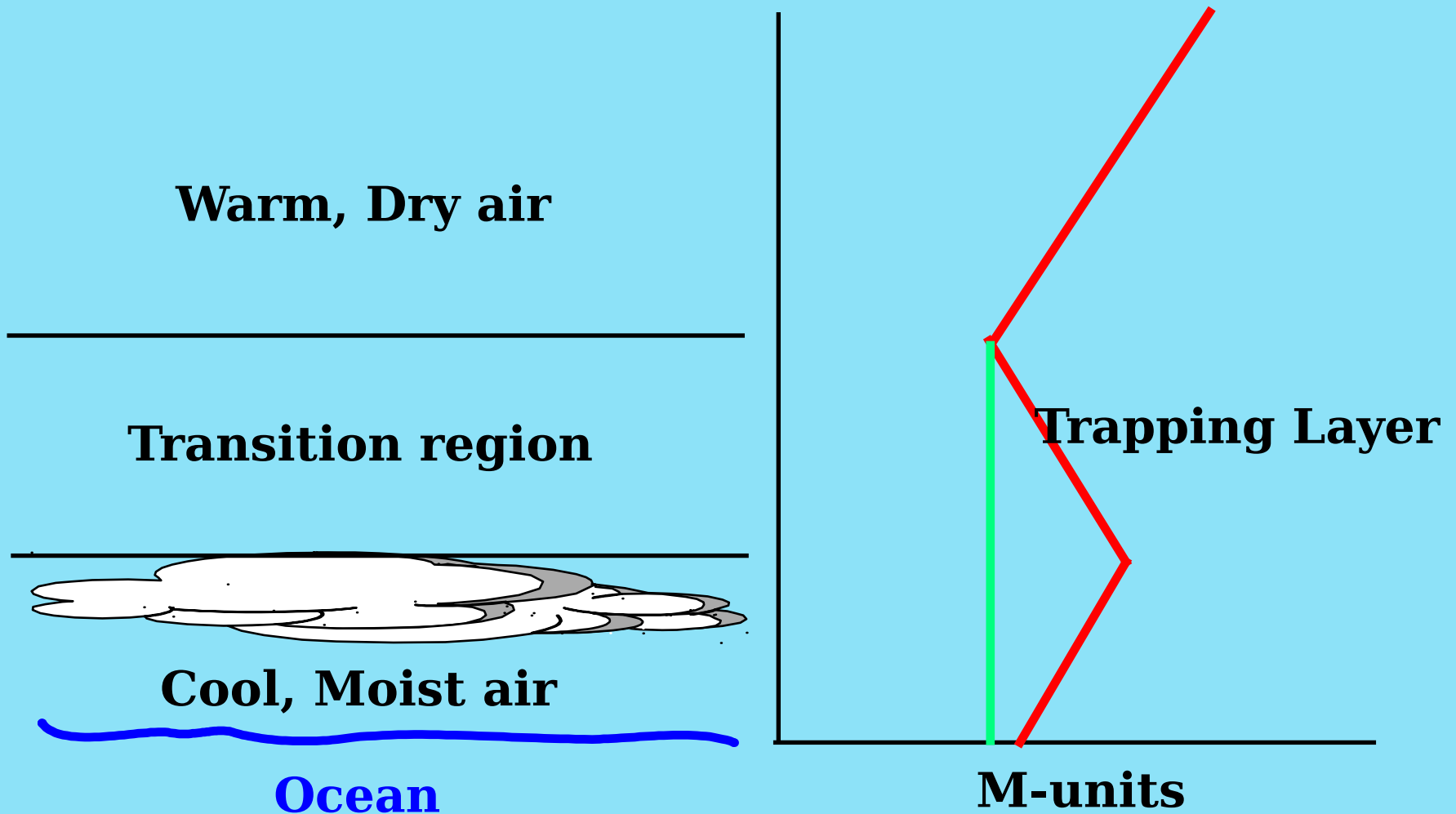
- ***ELEVATED***

- ***EVAPORATIVE***

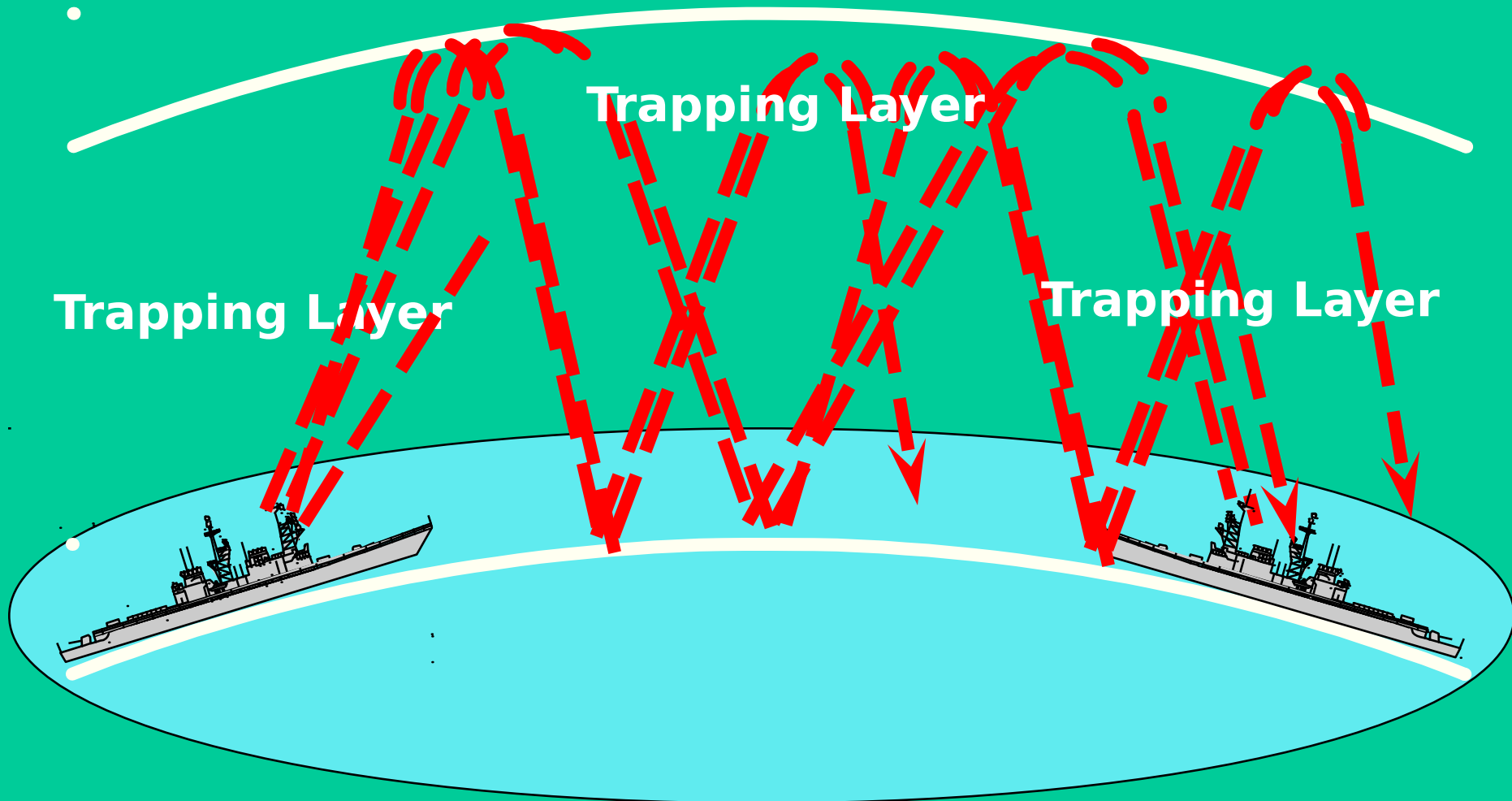
# ***SURFACE DUCT***

- Usually a fair weather phenomenon associated with temperature inversions
- **Overland:**
  - Radiative heat loss on clear nights
  - Moist ground causes moisture gradient
- **Over ocean:**
  - Warm, dry air advected over cool water

# ***SURFACE DUCT***



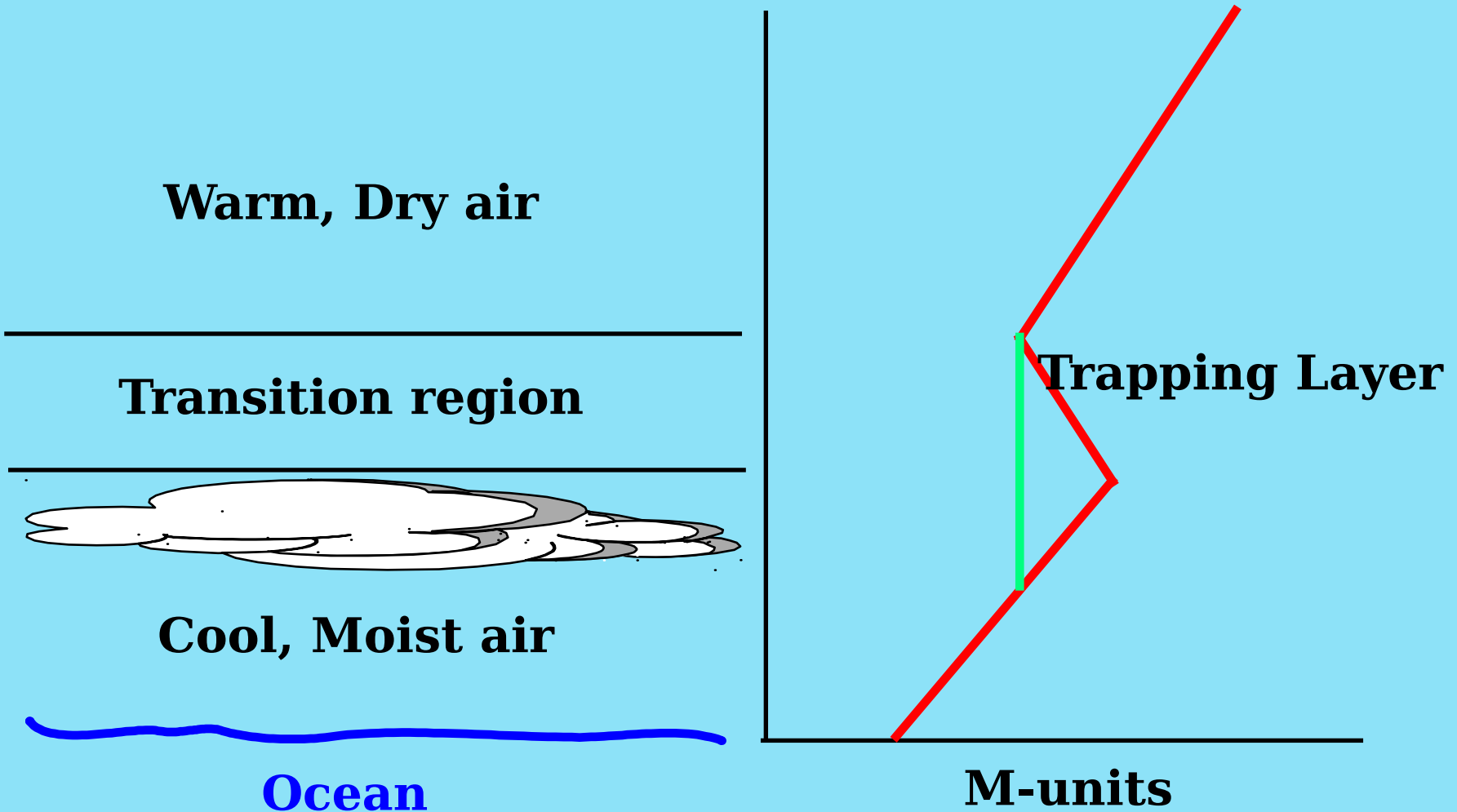
# ***SURFACE DUCT PROPAGATION***

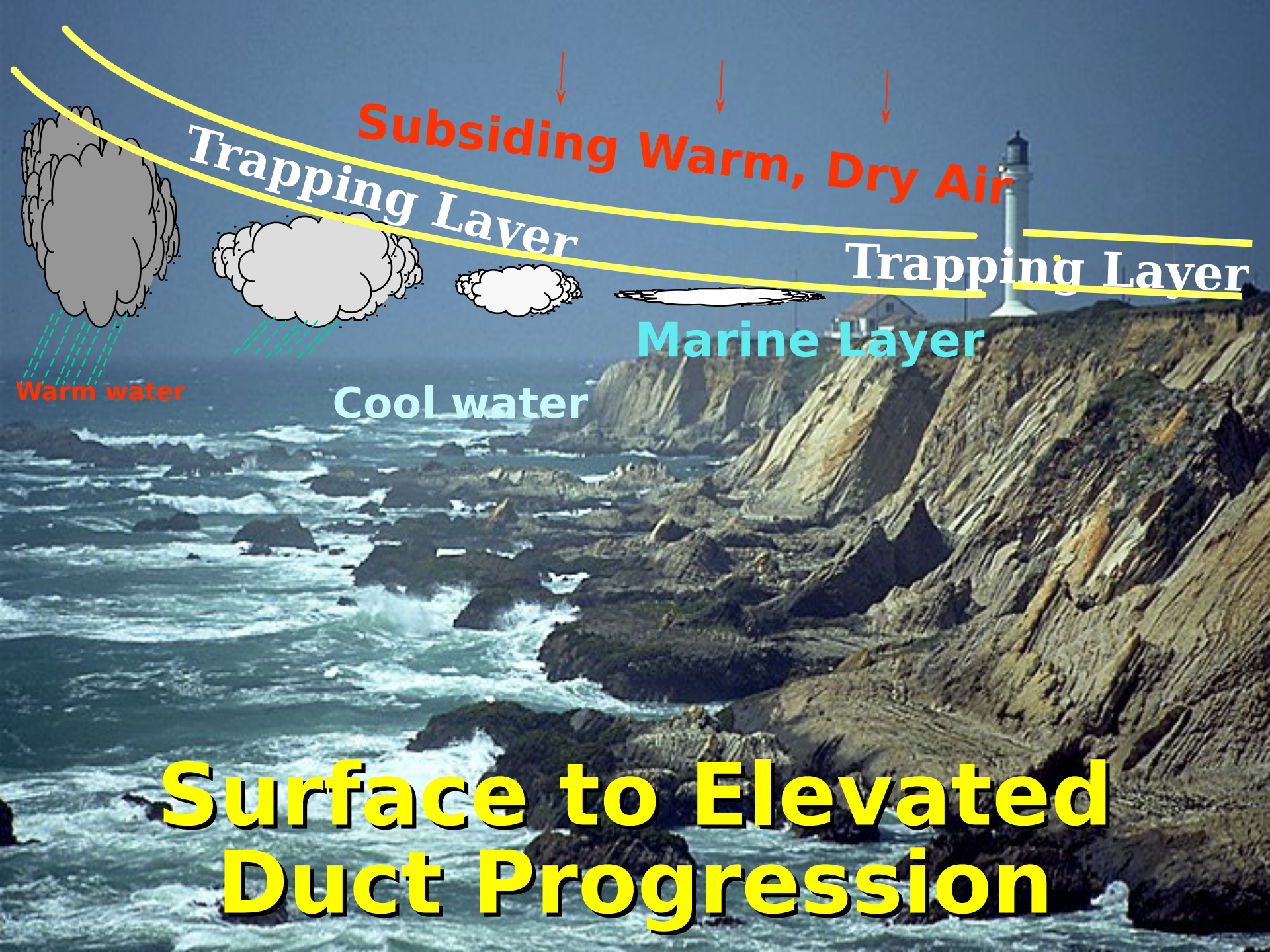


# ***ELEVATED DUCT***

- **Requires subsidence**
  - **Warm, dry air over cool, moist air**
- **Associated with large high pressure**
- **Lower and more prevalent on the eastern side of high pressure cells**
- **Often a continuation of a surface based duct (continental over maritime air masses)**
- **Elevated ducts are not tactically significant**

# ***ELEVATED DUCT***





**Subsiding Warm, Dry Air**

**Trapping Layer**

**Trapping Layer**

**Marine Layer**

**Warm water**

**Cool water**

**Surface to Elevated  
Duct Progression**

SUBSIDENCE

SUBSIDENCE

RISE MOTION

H

L

H

H

L

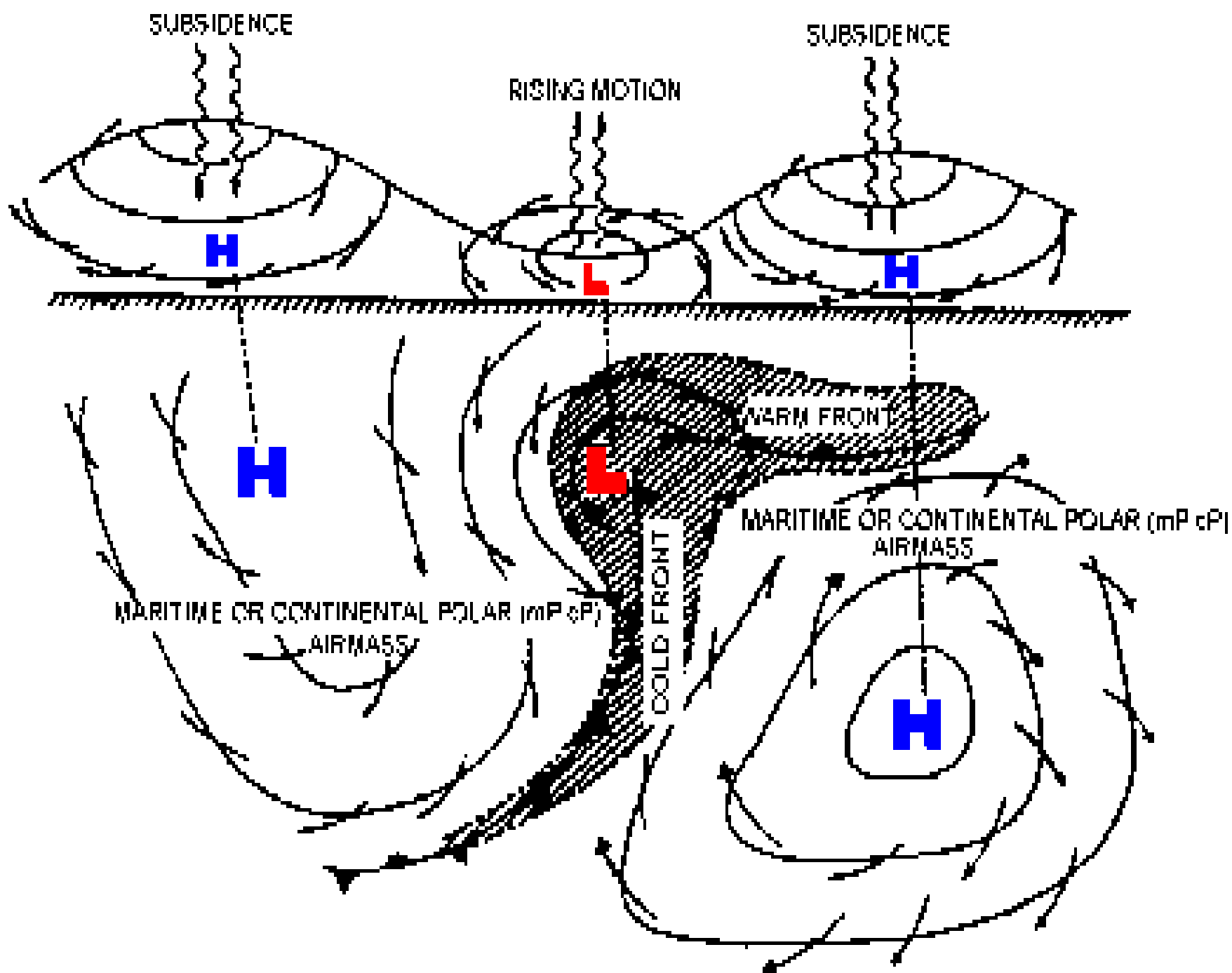
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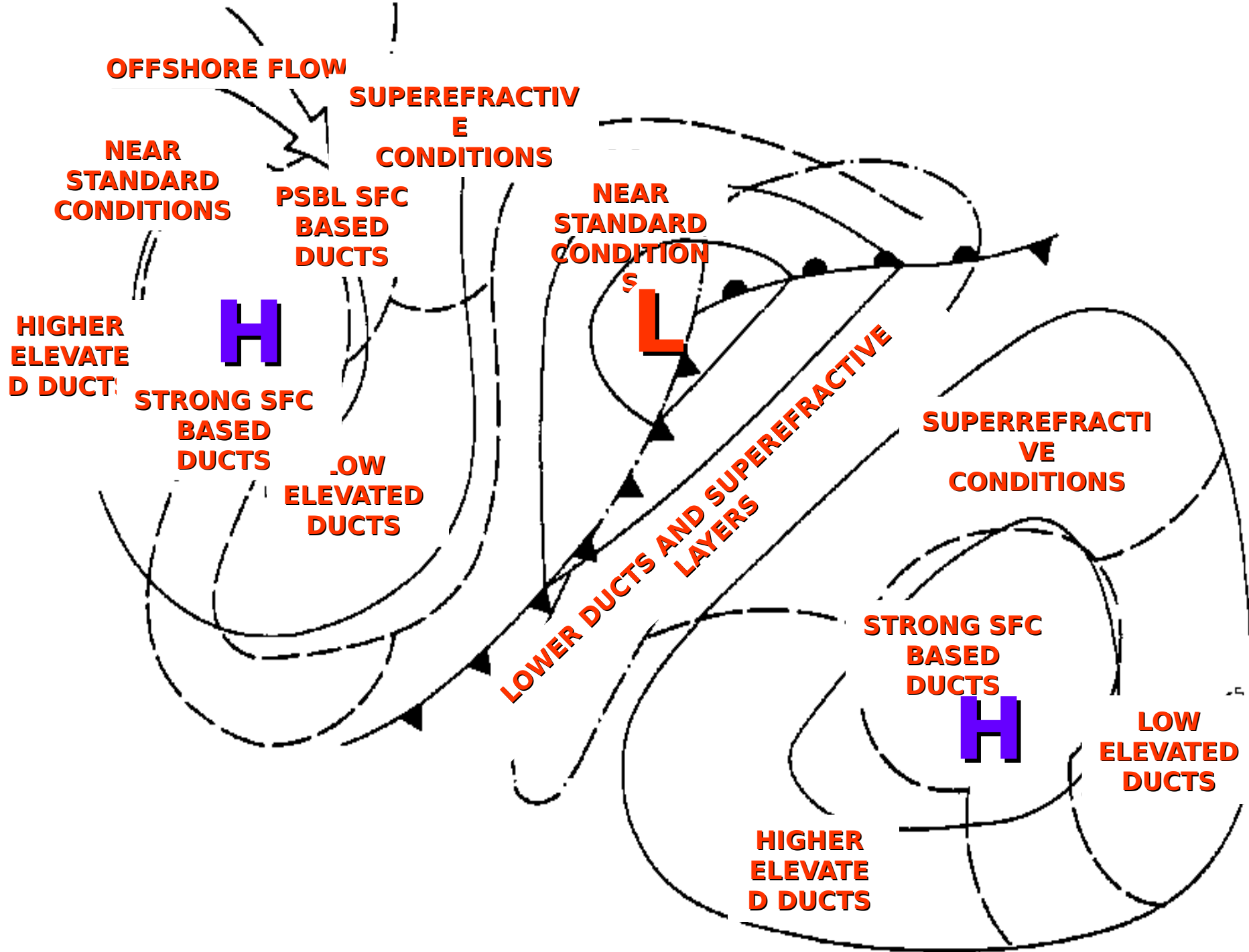
WARM FRONT

MARITIME OR CONTINENTAL POLAR (mP cP)  
AIRMASS

MARITIME OR CONTINENTAL POLAR (mP cP)  
AIRMASS

COLD FRONT





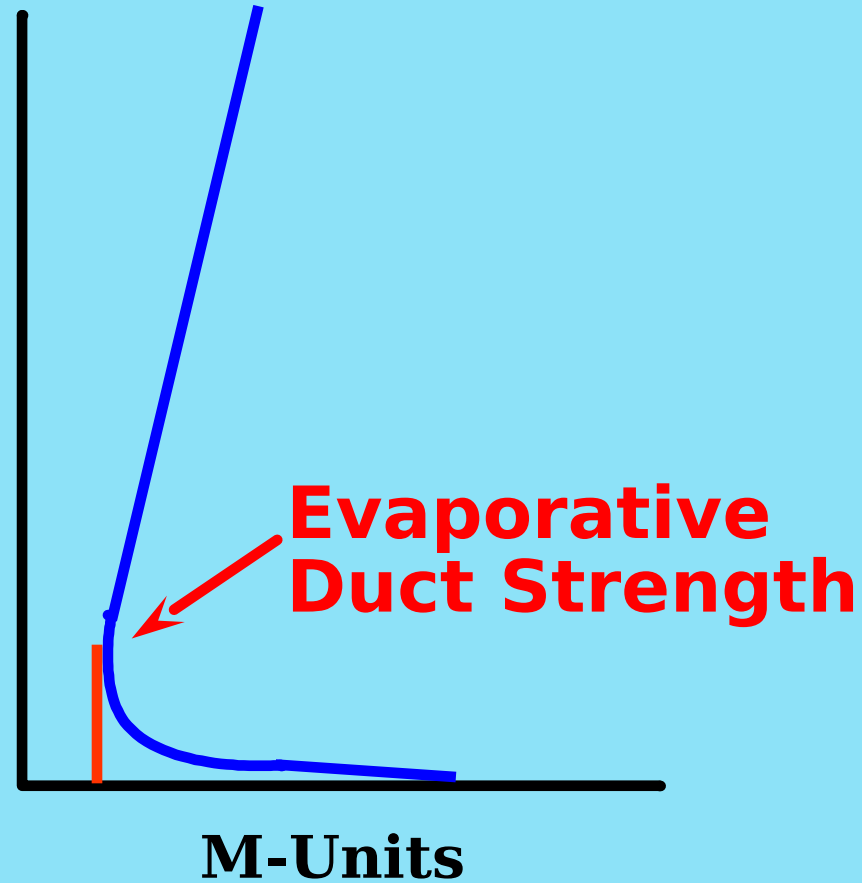
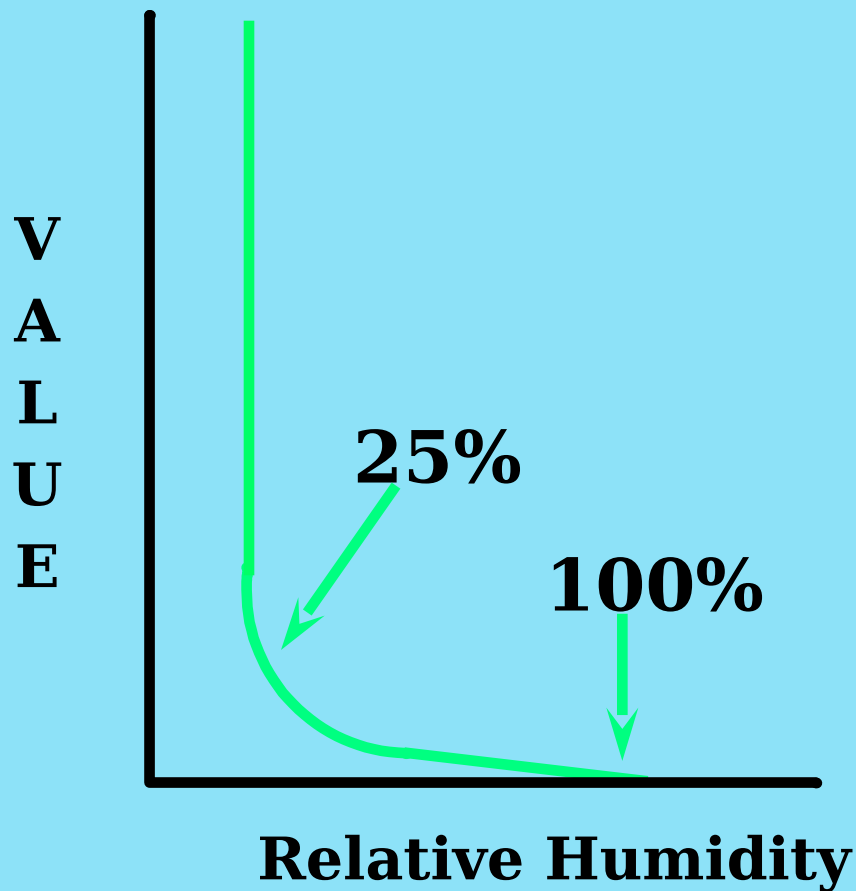
# ***EVAPORATIVE DUCT***

- **Evaporative Duct height is an indication of the ability to trap EM**
- **Antenna need not be "in" the duct to**
- **Very frequency dependent**
- **Can compute evaporative duct diurnal values using AREPS**

# ***EVAPORATIVE DUCT***

- **Air/Ocean interface**
- **Moisture variation only**
  - **Temperature nearly constant**
- **Strongest during equatorial summer**
- **Weakest during high latitude winter**
- **Global average height is 45 Feet**

# ***EVAPORATIVE DUCT***



# QUESTIONS

**1. What type of propagation condition would you typically expect in a Santa Ana? Why?**

Trapping propagation conditions. This is due to warm, dry continental air advecting over a cool, moist surface.

**2. Name the 3 types of ducts.**

Surface, Elevated, and Evaporative

**3. Is the Evaporative Duct frequency dependent? Why?**

Yes, it is very frequency dependent. The evaporative duct is only strong enough to affect EM systems above 2 GHz.

# QUESTIONS

**1. Are elevated ducts tactically significant? Why?**

**No, elevated ducts are not tactically significant because the altitude is too high to use with shipboard antennas. E-2C's flying in or near the duct will not detect aircraft flying above it.**

**2. How can you tell if trapping is occurring on your M-unit profile?**

**Negative gradient**

**3. What is the change in Modified Refractivity for superelevation?**

**0 to 24 M-units**